

Findings From Five Telemedicine Studies: Sufficiency and Standards

Steven H. Stumpf, EdD, Rod R. Zalunardo, EdD

University of Southern California Advanced BioTelecommunications and BioInformatics Center

sstumpf@abbc0.hsc.usc.edu

Until wireless, remote, robotic procedures are commonly deployed, telemedicine comprises two media formats: store-forward and live videoconferencing. This *prima facie* observation is the point at which early telemedicine research ends and new investigations begin. Findings from five telemedicine studies that fall within the realm of new telemedicine investigations follow. The five studies did not investigate ways in which telecommunications applications can be adapted to medical disciplines. The advance of technology into all areas of medicine is inevitable. Each study investigated the *implementation* and *evaluation* of telemedicine standards and systems; three on image quality, one on eye care, and one on videoconferencing in a remote trauma center. We called the projects Digital Gold, Image Artifacts, Screening the Underserved, Remote ER, and Eye Care for Underserved.

The delivery of eye care for underserved populations in community clinics was dramatically improved with the implementation of a digital system in the office of a primary care provider. In one study, the compliance rate for patients with diabetes who should receive annual eye exams improved from 54 to 83 percent, a proportional improvement of 54 percent.

An unanticipated finding confirmed by two studies was that disadvantaged patients were receiving sufficient primary care for diabetes despite the oft-cited barriers to care. However, specialty care was still absent and not accessible. The presence of nonmydriatic fundoscopic cameras immediately filled the specialty-care deficit. Telemedicine works, especially in underserved communities, when properly applied using the correct technologies.

Replication and ease of implementation cannot be overemphasized.

The Remote ER study demonstrated the need to reevaluate the reliability of bandwidth standards for connectivity (Integrated Services Digital Network [ISDN] versus digital subscriber line) as the deployment of telemedicine expands in rural and urban areas. Videoconferencing over public phone lines (ISDN) is problem prone. When available, more reliable and more cost-efficient Internet Protocol solutions are preferred. New telemedicine projects should continue to critically investigate connection standards from point-to-point T1 circuits to land-based wireless networks. The Remote ER and Eye Care for Underserved studies demonstrated that telemedicine can be implemented fairly easily, to the benefit of more populations, utilizing more technologies.

Image-quality findings provided more detail than had previously existed concerning the utility of digital images in diagnosing eye disease. All three generally recommended (with various caveats) using digital images for screening out pathology (specificity). However, investigators differed importantly on many points regarding the sensitivity of digital images and their usefulness for diagnosing specific eye disease (sensitivity). The Image Artifacts investigators found 96 percent of images in their study unacceptable for screening diabetic retinopathy. The Digital Gold and Screening the Underserved investigators found that sensitivity levels fell below acceptable levels for diagnosing specific disease. However, they agreed that camera operator training was an important prerequisite for ensuring collection of high-quality images. Interestingly, at least two-

thirds of the images designated as unsuitable by the Image Artifacts investigators were attributable, by their own findings, to operator error.

The differences among investigators' findings caused us to question whether an image-quality gold standard based on the properties of film is appropriate for evaluating digital images. Perhaps the gold standard based on 35 mm film must be reconsidered altogether to most effectively optimize the utility of digital images in medical care.

The advantages of digital imaging did not really weigh in the studies. For example, digital images do not suffer the image erosion found in photographs as they are moved from capture to viewing device (film to photo stock). In analog photography, an image loses quality (e.g, noise, resolution, and dynamic range) every time it is transposed. This does not occur in the digital domain. The key to every high-quality digital image is to acquire a noise-free, high-resolution, color-accurate image at the outset. Ultimately, because of the nature of the medium, digital images may represent a superior method for attaining this objective.

In any digital medium, three main phenomena affect overall perception of picture quality:

- (1) signal to noise (less noise is desirable to reduce errors in information), (2) resolution (i.e., the absolute level of detail of a digital picture), and
- (3) dynamic range (i.e., the capability to contrast light with dark and to heighten color sharpness with great clarity and accuracy). In each of these considerations, a 32-bit image yields higher quality than a 24-bit image. These three areas are the essence of all digital media, including digital photography. Reduction in any one affects the overall quality of the image being produced. Conversely, the ability to exert greater control over each factor optimizes image quality. Once the digital

image is captured under the most optimal conditions (including not only lighting and lens but also pixel depth), that image can be manipulated so that the image is improved without distorting it.

An example of how digital photography can be more easily (and advantageously) manipulated without distorting and even enhancing the image is the ability to change an image from a positive to a negative. Certain phenomena can be seen more readily and even more clearly in negative. A good example is a picture of stars at night. In a regular photo, it is very difficult to see low-light-level stars as white dots on a black background. However, the negative image, wherein stars appear as black dots on a white background, permits dim stars to be seen much more easily. This effect is due to the dynamic range of human eyes. We are able to more easily pick out a small black spot on a white background than a small white spot on a dark or black background. Future image-quality research should approach quality on terms compatible and congruent with the digital medium instead of film. Established standards germane to film should be eschewed in favor of discovering new standards compatible with the strengths of digital images. Likewise, new and innovative methods of using digital images must be discovered to test the new standards.

We have continued with several studies since the formal end of the National Library of Medicine (NLM) project. The Remote ER project at the hyperbaric chamber on Catalina Island is being expanded to include teleradiology between the local paramedics and clinical departments at the University of Southern California (USC) Keck School of Medicine departments. An electronic link is being established between the Avalon Hospital Medical Center and the island's most remote community (population of 300) near the chamber to create a telemedicine primary care kiosk at the chamber. The willingness of the community to entertain

a telemedicine solution is a direct result of the efforts and outcomes that arose from the NLM project.

The two eye care screening programs continue to provide services to underserved populations in south and central Los Angeles. Two additional sites that serve uninsured populations in east Los Angeles and Orange County have received nonmydriatic fundoscopic cameras and are participating in studies replicating the eye care studies supported by the NLM project. These projects will extend the image-quality research while immediately eliminating the barrier to specialty eye care for patients with diabetes in Los Angeles' most underserved communities.

Telemedicine may be a commonplace reality, but it is not a finished product. In continuing our applications research in telemedicine, we shall heed the advice of one of our NLM investigator teams, paraphrased and interpreted below for a broader audience:

It would behoove all of us to modify or limit ongoing telemedicine efforts to reflect the following: The benefit of telemedicine in reaching those who would otherwise have no care must be weighed against the harm suffered by those whose conditions are misclassified because telemedicine has been applied without considering its place in the continuity of care.

The Advanced BioTelecommunications and BioInformatics Center is a telemedicine applications research center located on the USC Health Sciences Campus in east Los Angeles.

ACKNOWLEDGMENT

This project has been funded in part with Federal funds from the National Library of Medicine under Contract No. N01-LM-6-3543.